RESEARCH, DEVELOPMENT & TECHNOLOGY TRANSFER
QUARTERLY PROGRESS REPORT

Wisconsin Department of Transportation
DT1241 02/2011

INSTRUCTIONS:
Research project investigators and/or project managers should complete a quarterly progress report (QPR) for each calendar quarter during which the projects are active.

WisDOT research program category: ☐ Policy research ☒ Wisconsin Highway Research Program ☐ Other ☐ Pooled fund TPF#		Report period year: 2012 ☐ Quarter 1 (Jan 1 – Mar 31) ☒ Quarter 2 (Apr 1 – Jun 30) ☐ Quarter 3 (Jul 1 – Sep 30) ☐ Quarter 4 (Oct 1 – Dec 31)
Project title: Aesthetic Coatings for Bridge Components		
Project investigator: Dr. Al Ghorbanpoor	Phone: 414-229-4962	E-mail: algh@uwm.edu
Administrative contact: Nikki Hatch	Phone:	E-mail:
WisDOT contact: Travis McDaniel	Phone: 608-266-5097	E-mail: travis.mcdaniel@dot.state.wi.us
WisDOT project ID: 0092-11-07	Other project ID:	Project start date: 10/21/2010
Original end date: 10/20/2012	Current end date: 10/20/2012	Number of extensions: 0

Project schedule status:

☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Project budget status:

Total Project Budget	Expenditures Current Quarter	Total Expenditures	% Funds Expended	% Work Completed
$145,000.00	$20,000.00	$108,000.00	74%	70%

Project description:

The objectives of this study are to investigate methods and products that may be used in the aesthetic and protection coating of bridge components and to develop a guideline for cost-effective bridge coating practices. It was envisioned that a series of coating systems for both steel and concrete would be identified and tested in the laboratory to evaluate their performance under simulated environmental conditions that are similar to those experienced by bridge components in Wisconsin. After conducting a preliminary investigation and holding discussions with the Project Oversight Committee (POC), it was approved by the POC that the focused should be placed on evaluation of only steel materials due to the extensive nature of the required investigation and scope of the current study. Wisconsin bridge sites, where coating failures and problems have occurred, have been visited to identify and evaluate the structural details and other factors that have contributed to such coating failures. Upon completion of the testing and evaluation program, guidelines and specifications language will be developed for selection, application, and maintenance of such coating materials. Also, recommendations will be made to WisDOT for implementation of the results of this study.

Progress this quarter (includes meetings, work plan status, contract status, significant progress, etc.):

During this quarter the research staff has continued the Freeze/UV/Prohesion and Xenon Arc testing. Four cycles of Freeze/UV/Prohesion have been completed and eight cycles of Xenon Arc testing have been completed. A cycle of Freeze/UV/Prohesion consists of a 24-hour freeze, one week in UV chamber, and one week in salt-fog chamber. A cycle of Xenon Arc consists of one week in the Xenon Arc chamber with repeating 2-hour cycles of 1 hour and 42 minutes of Xenon light and 18 minutes of Xenon light with water spray.

At the end of each cycle of Freeze/UV/Prohesion the 3"x6" samples are measured for changes in color and gloss, rust creepage, holidays, and dry film thickness. The 4"x6" samples in the Freeze/UV/Prohesion are used to measure the change in flexibility from the control samples to the weathered samples. For each cycle, the 2"x2" samples in the Xenon Arc testing are measured for change in gloss and color, and dry film thickness. Additionally, the research staff has been conducting adhesion tests on the 3"x6" control samples. The control adhesions test will be compared to the adhesion tests on the weathered 3"x6" samples upon testing completion.

An important component to evaluate the aesthetics of a coating system is the change in color. Change in color is represented by calculating a ΔE value. ΔE is the root mean square of the change in the (L), (a), and (b) values in the color index system, $\Delta E = SQRT\ ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)$. This represents the total color difference between the initial color reading and color readings after each cycle. The (L) value in the color index systems represents how white or black an object is. The scale for the (L) value ranges from 0 (black) to 100 (white). The (a) value represent the color range from green to red, and the scale ranges from negative (-100) to positive (+100). Negative (-a) indicates a green color and positive (+a) indicates a red color. Finally, the (b) value represents the color range from blue to yellow with a scale also ranging from (-100) to (+100). Negative (-b) indicates a blue color and positive (+b) indicates a yellow color

For the Freeze/UV/Prohesion test, it is too early in the test to predict trends, but to date, both two-coat systems in the test program show higher ΔE values than all but two coating systems. The mid-grade duplex polyester powder coating system has the highest ΔE values and the fading in the color of these samples are visually noticeable. The conventional liquid fluoropolymer coating systems and powder coated fluoropolymer coating systems have the lowest ΔE values, with very little change in color. The non-galvanized samples all have rust forming in the scribe, but to date no samples have had rust creepage at the scribe. The galvanized samples do not have any rust forming at the scribe.

The percent change in color for the Xenon Arc testing has similar trends to the results of the Freeze/UV/Prohesion testing. Also, the fluoropolymer coatings are experiencing lower ΔE values compared to the majority of the coatings. The two-coat coatings are not showing higher ΔE compared to the rest of the coating system, as was the case in the Freeze/UV/Prohesion testing.

Please see Appendix "B" at the end of this progress report for more detailed results of the laboratory test as of June 15, 2012.

Anticipated work next quarter:

The research staff will continue the test program on all the selected coated samples. During the testing phase, the coated samples will be subjected to two different tests. One test will consist of Freeze/UV/Prohesion cycles and the other test will consist of the Xenon Arc testing. The test panels will be evaluated every two weeks for the effects of the Freeze/UV/Prohesion test and every week for the effects of the Xenon Arc testing. The bi-weekly and weekly evaluation will include measuring changes in color and gloss, rust creepage, holidays, and dry film thickness for the test samples. Samples will also be photographed bi-weekly for Freeze/UV/Prohesion test program and weekly for Xenon testing. Additionally, the research staff will continue to conduct adhesion test on the 3"x6" control samples and also begin testing scratch hardness on the 3"x6" control samples. Finally, the flexibility of the coatings will be measured on the 4"x6" control samples using a mandrel bending apparatus.

Circumstances affecting project or budget:

None.

Attach / insert Gantt chart and other project documentation

Quarters/Tasks	1	2	3	4	5	6	7	8
1. Literature Review								
2. Survey								
3. Interim Report								
4. Laboratory Testing								
5. Future Research								
6. Guidelines/Specs								
7. Draft Final report								
8. Final Report								

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Staff receiving QPR:	Date received:
Staff approving QPR:	Date approved:

Test Program
(Approved by POC on September 22, 2011)

Aesthetic Coatings for Bridge Components

WHRP Project # 0092-11-07

By

Al Ghorbanpoor and Zan Leppi
University of Wisconsin-Milwaukee

September 26, 2011

Introduction

To meet the requirements of the current WHRP study entitled "Aesthetic Coatings for Bridge Components," the research team submitted a proposal on September 14, 2011 to the Project Oversight Committee (POC) and WHRP to seek approval for the proposed testing program to be performed during the remaining term of this study. The proposal included two options which were both limited to testing coating systems for only new steel applications. The proposed options included a testing program of either 10 or 12 coating systems under two color schemes. The program as approved by the POC includes the 12-coating system option that consists of a slightly smaller number of test samples for the Xenon and Mandrel testing components. Through a correspondence on September 22, 2011, the POC forwarded to the research team a final approval for the test program as detailed below.

Approved Coating Systems and Test Program

The following table shows 12 coating systems for new steel applications, along with the number of samples, and the type of tests that will be performed on these coating systems. A description of each coating system is shown in appendix "A". There will be 5 samples per coating system for the UV/Prohesion/Freeze tests (Alternate ASTM D5894), and 2 samples per coating system for Mandrel testing. For Xenon testing, there will be 3 samples per coating systems tested with the following exception. The top-coats for coatings systems #A and #M and for #C and #N are the same so we will achieve the same results by performing tests on only coating systems #A and #C. Accordingly, we will eliminate the Xenon tests for coating systems #M and #N, to meet the space limitation of the Xenon testing equipment. For all UV/Prohesion/Freeze and mandrel tests, the Federal Color Number (27038) black will be used. For the Xenon tests, the Federal Color Number (27038) black and Federal Color Number (15092) blue will be used. Accordingly, a complete Xenon testing program of a minimum of 1,000 hours will be performed for samples coated with each selected color.

Approved 12 Coating Systems

System Type and #	Number of Systems	# of 3x6x1/8 in. Samples for UV/Prohesion/Freeze Testing (Alternate ASTM D5894)	# of 2x2x1/8in. Samples for Xenon Testing (ASTM G155)	# of 4x6x1/32in. Samples for UV/Prohesion/Freeze Mandrel Testing[2]
3-Coat Polyurethane (#A, #C, #Y)	3	15	9	6
3-Coat Fluoropolymer (#B, #Z)	2	10	6	4
2-Coat (#F, #0)	2	10	6	4
Galvanized Paint (#M, #N, #X)	3	15	3[1]	6
Galvanized Powder (#AA, #AB)	2	10	6	4
Total	12	60	30	24

[1] Tests applies to coating system #X only. Note that top coats are the same for coating #A and #M and for #C and #N.

[2] 2 samples per coating system will be tested under the Mandrel tests.

Appendix “A”
(Description of Coating Systems)

3-Coat Polyurethane Systems

Coating #	Manufacture	3-Coat System	Primer /DFT(mils)	Intermediate Coat /DFT(mils)	Top Coat /DFT(mils)
A	Sherwin Williams	Polyurethane	Zinc Clad III /(3-6)	Macropoxy 646 /(3-10)	Acrolon 218 HS /(3-6)
C	Carboline	Polyurethane	Carbozinc 859 /(3-5)	Carboguard 888 /(3-5)	Carbothane 133LH /(3-5)
Y	PPG	Polyurethane	Amercoat 68HS /(3)	Amercoat 399 /(4-8)	Amercoat 450H /(2-5)

3-Coat Fluoropolymer Systems

Coating #	Manufacture	3-Coat System	Primer /DFT(mils)	Intermediate-Coat /DFT(mils)	Top-Coat /DFT(mils)
B	Sherwin Williams	Fluoropolymer	Zinc Clad III /(3-6)	Macropoxy 646 /(3-10)	Fluorokem /(2.5-3)
Z	Carboline	Fluoropolymer	Carbozinc 859 /(3-5)	Carboguard 888 /(3-5)	Carboxane 950 /(2-3)

2-Coat Systems

Coating #	Manufacture	**1st Coat/DFT**(mils)	**2nd Coat /DFT**(mils)
F	Carboline	Carbozinc 859 /(5-7)	Carboxane 2000 /(7)
O	Sherwin Williams	Corothane I Galvapac Zinc /(3-4)	Polysiloxane XLE-80 /(3-7)

Galvanized Systems with Paint Coats

Coating #	Manufacture	**Tie-Coat/DFT**(mils)	**Top-Coat/DFT**(mils)
M	Sherwin Williams	Macropoxy 646 /(2-4)	Acrolon 218 HS /(2-4)
N	Carboline	Galoseal WB /(0.5-1)	Carbothane 133LH /(3-5)
X	Wasser	MC-Ferrox B 100 /(3-5)	MC-Luster 100 /(2-4)

Galvanized Systems with Powder Coat

Coating #	Manufacture	**Tie-Coat/DFT**(mils)	**Top-Coat/DFT**(mils)
AA	Sherwin Williams	EAS6-C000 Epoxy /(1.8-3)	AAMA 2605 Fluoropolymer /(2-3)
AB	Sherwin Williams	EAS6-C000 Epoxy /(1.8-3)	AAMA 2604 Polyester /(2-3)

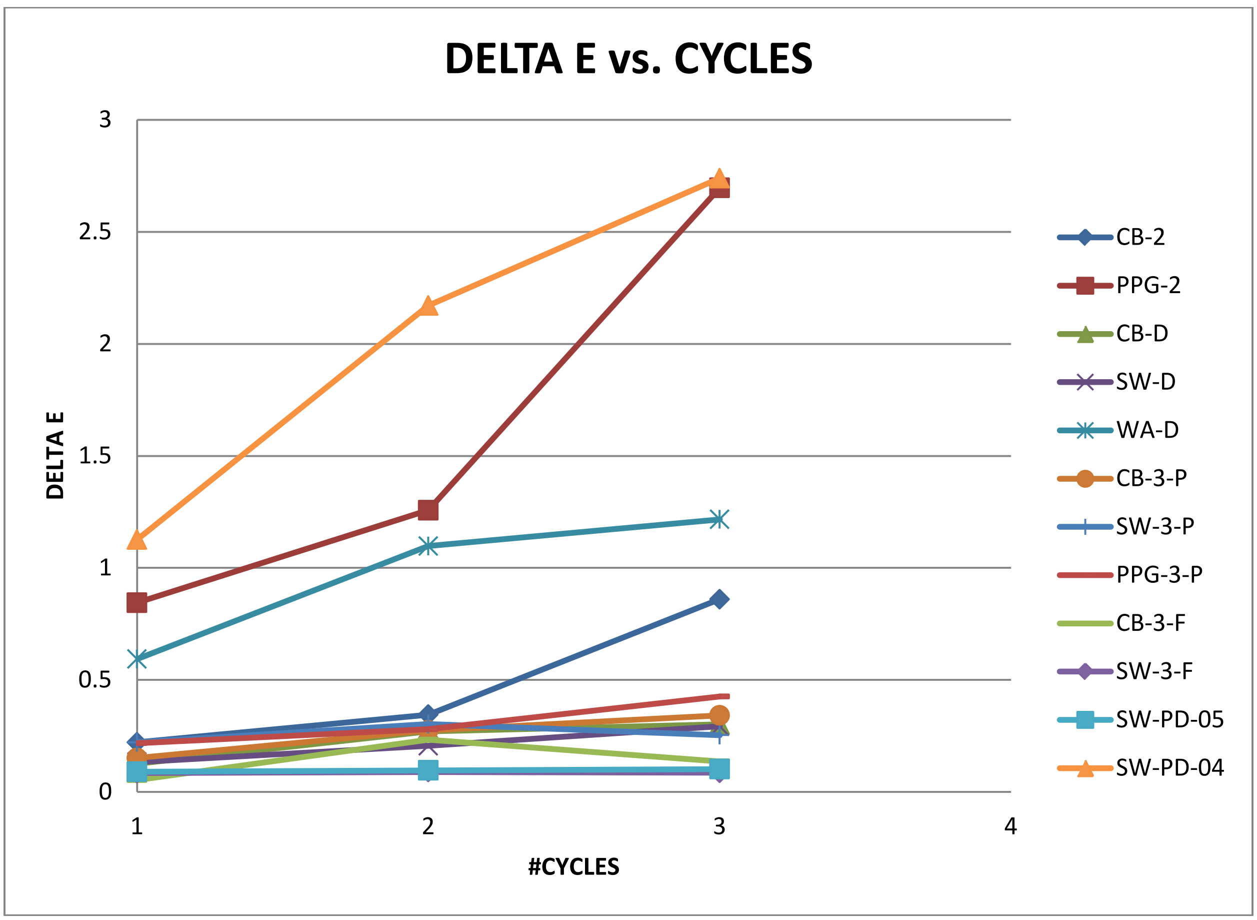
Appendix "B"
Laboratory Test Results (As of June 15, 2012)

I. Freeze/ UV/ Prohesion Testing

Three cycles of the Freeze/UV/Prohesion testing have been completed. A cycle consists of a 24hour freeze, 1 week UV, and 1 week salt fog. So far no samples have had rust creepage at the scribe. The non-galvanized samples all have rust forming in the scribe, but so far no samples have had rust creepage at the scribe. The galvanized samples do not have any rust forming at the scribe.

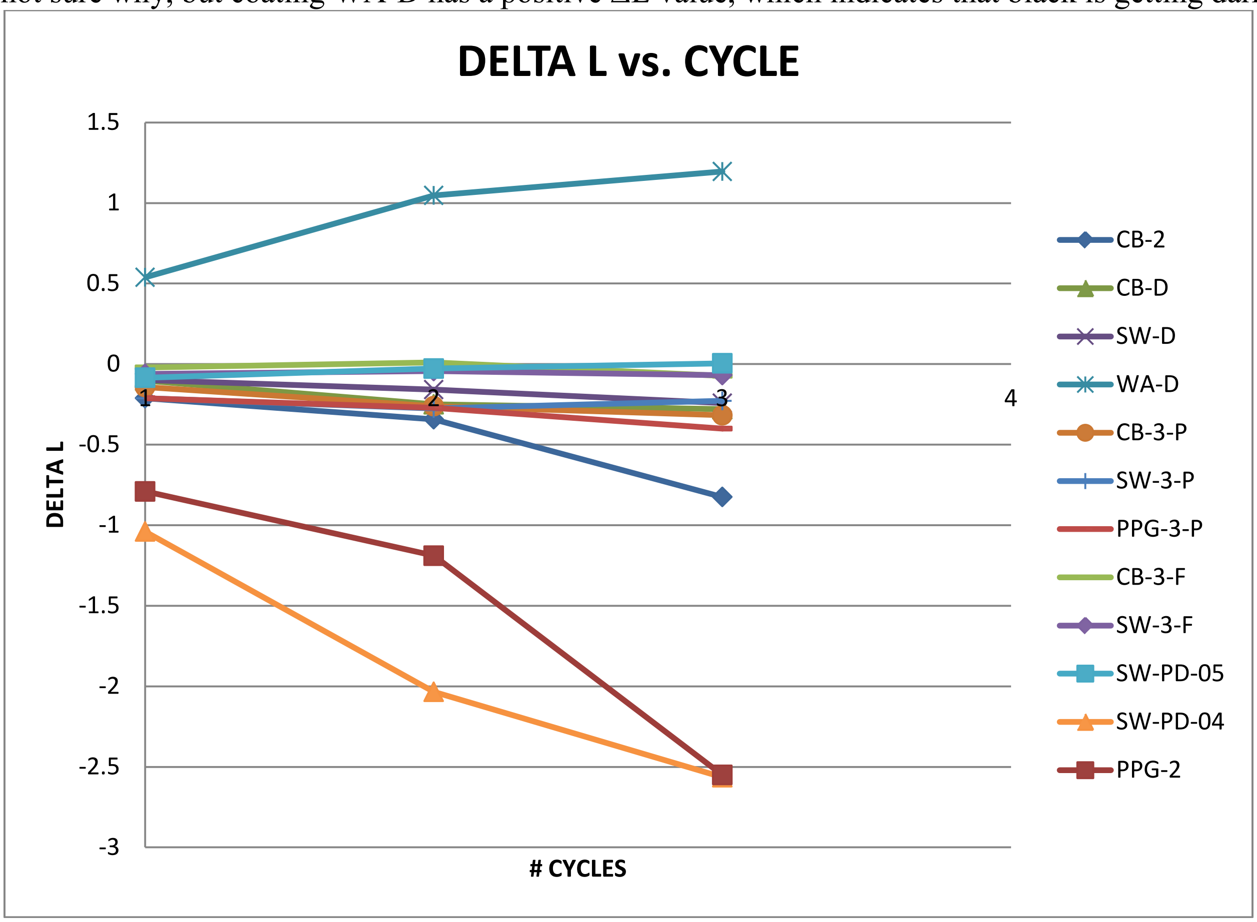
In graph #1 the change in color is represented by ΔE. ΔE is the root mean square of the change in the (L), (a), and (b) values in the color index system, $\Delta E = SQRT\ ((\Delta L)^2+(\Delta a)^2+(\Delta b)^2)$. This represents the total color difference between the initial color reading and color readings after each cycle. The (L) value in the color index systems represents how white or black an object is. The scale for the (L) value ranges from 0 (black) to 100 (white). The (a) value represent the color range from green to red, and the scale ranges from negative (-100) to positive (+100). Negative (-a) indicates a green color and positive (+a) indicates a red color. Finally, the (b) value represents the color range from blue to yellow with a scale also ranging from (-100) to (+100). Negative (-b) indicates a blue color and positive (+b) indicates a yellow color.

It is too early in the test to predict trends, but so far both two coat systems do have higher ΔE values then the majority of the coatings. Duplex powder coating SW-PD-04 has the highest ΔE values and the fading in the color of these samples are visually noticeable. The conventional (SW-3-F and CB-3-F) and powder coated (SW-PD-05) fluoropolymer coatings have the lowest ΔE values, with almost no change in color.



Graph #1: ΔE vs. Number of Cycles

Since the samples are coated black it is also important to look at how the color black is changing throughout each cycle. To look at how the color black is changing in the samples ΔL is graphed. Graph #2 looks the ΔL values for all of the samples throughout each cycle. A negative ΔL values indicates that the color is getting lighter, or has a higher L value. Again, both two coat systems have larger negative ΔL values than all samples, except for the duplex powder coating SW-PD-04. Also, the conventional (SW-3-F and CB-3-F) and powder coated (SW-PD-05) fluoropolymer coatings have practically no change in L value from initial readings. I am not sure why, but coating WA-D has a positive ΔL value, which indicates that black is getting darker.

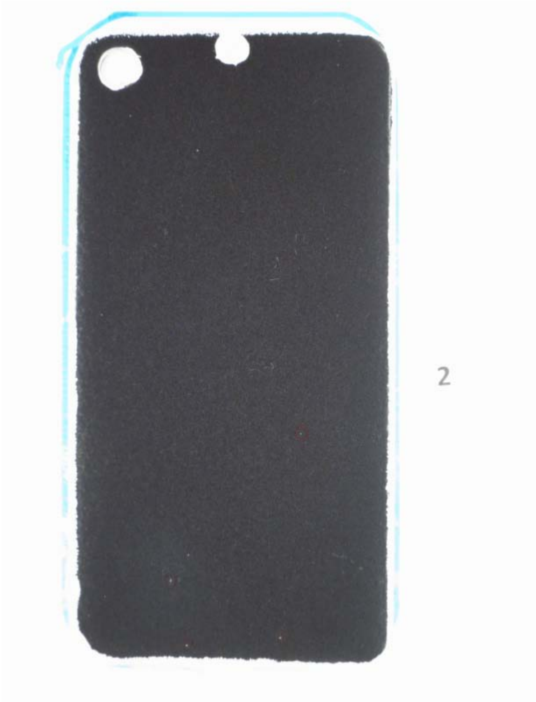


Graph #2: ΔL vs. Number of Cycles

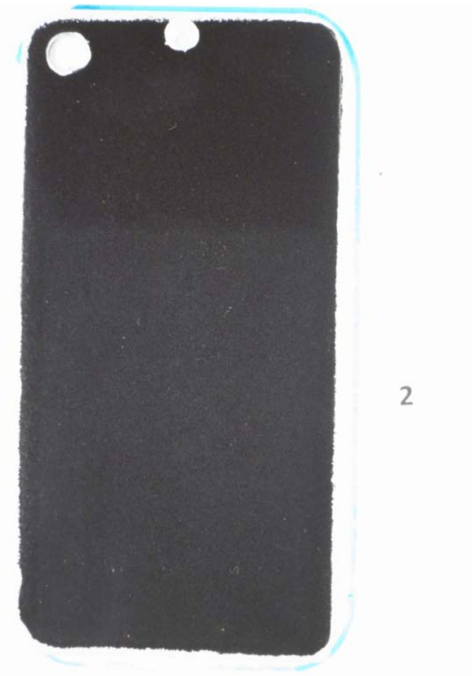
A visual representation of the change in color is shown in the figures below. Figure #1 shows pictures of coating system SW-PD-04 throughout each cycle, and figure #2 shows pictures of SW-PD-05 throughout each cycle. Coating system SW-PD-04 has a more noticeable change in color, with an average ΔE=2.74 and ΔL=-2.56 after 3 cycles, compared to coating systems SW-PD-05, which has no noticeable change in color, and average readings of ΔE=0.10 and ΔL=0.005.

Figure #1: Coating System SW-PD-04

INITIAL: ΔE=0 and ΔL=0



CYCLE #1: ΔE=1.127 and ΔL=-1.039



CYCLE #2: ΔE=2.171 and ΔL=-2.033

CYCLE #3: ΔE=2.739 and ΔL=-2.564

Figure #2: Coating System SW-PD-05

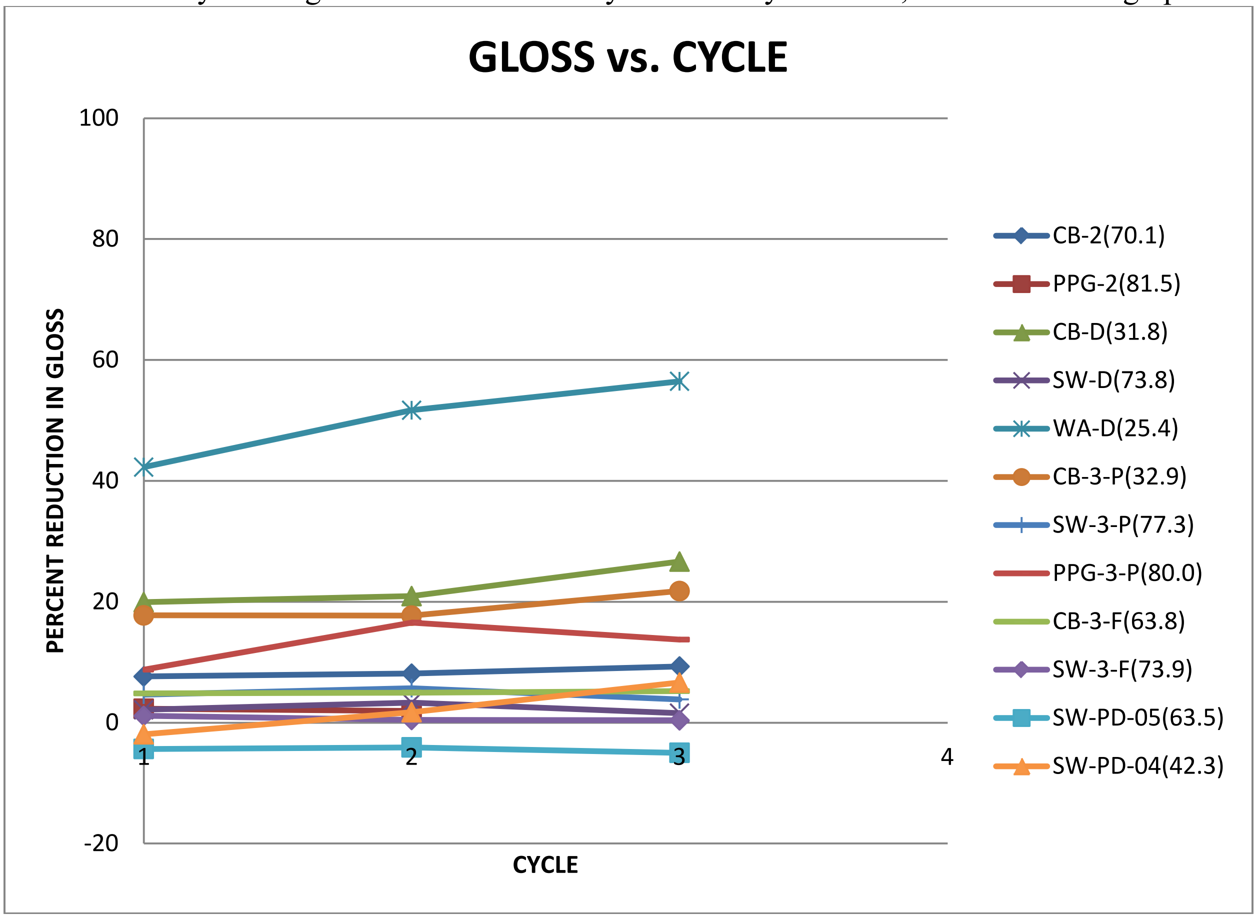
INITIAL: ΔE=0 and ΔL=0

CYCLE #1: ΔE=0.090 and ΔL=-0.084

CYCLE #2: ΔE=0.096 and ΔL=-0.028

CYCLE #3: ΔE=0.100 and ΔL=0.005

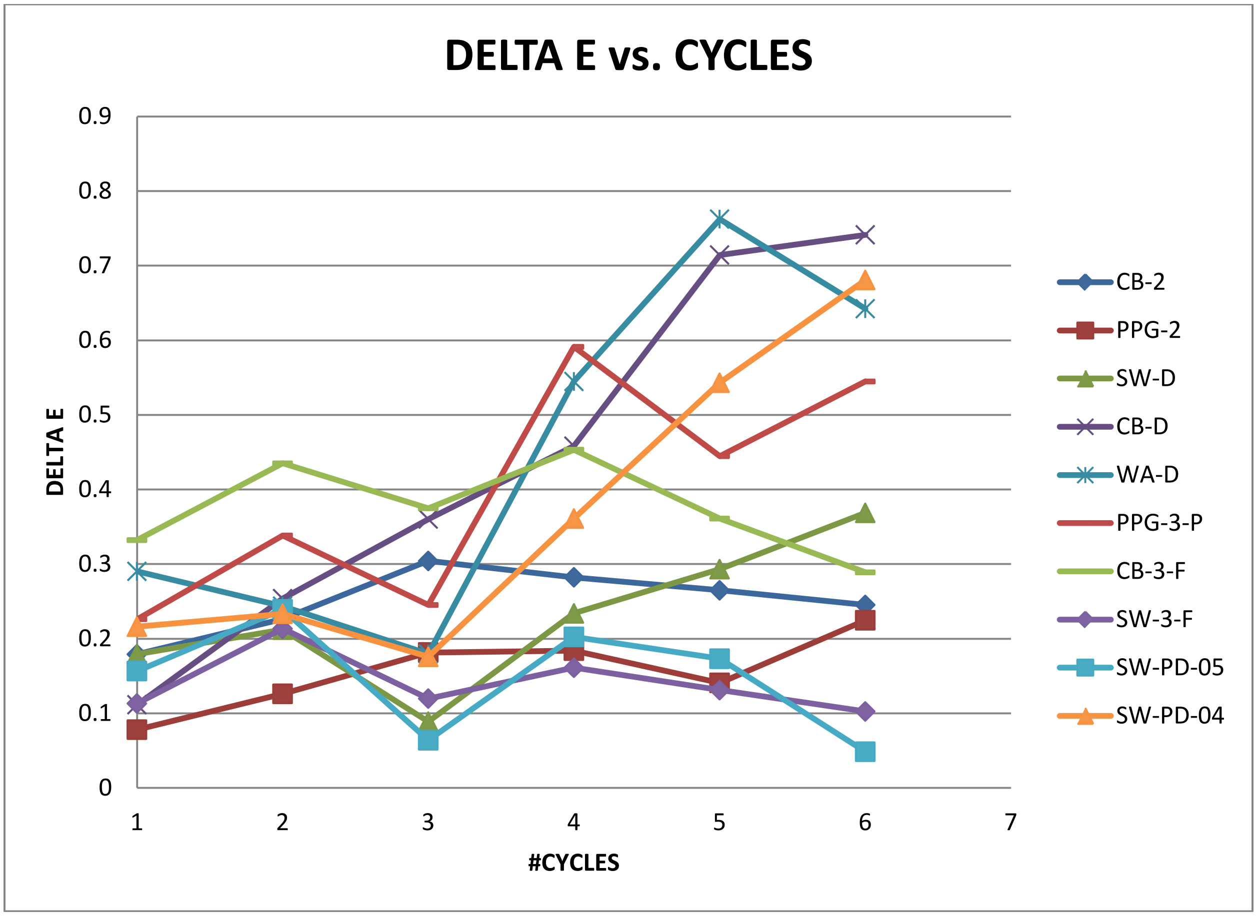
Additionally, the percent reduction in gloss from the initial value is shown in Graph #3. Not all samples had the same gloss values, so the percent reduction in gloss is represented in this graph. On the right hand side of the graph the initial gloss values are shown in parenthesis next to the sample identification. Gloss ranges from 0 (no gloss) to 100. Coating system SW-PD-05 actually had a small increase in gloss from its initial reading. The increase in gloss went from an initial average gloss of 63.5 to an average gloss of 66.3 after the first cycle. This is believed to be from the outgassing agent that was added to the powder coating during application. This outgassing agent leaves a wax residue on the coating that was removed after one cycle of Freeze/UV/Prohesion. After the first cycle the gloss on SW-PD-05 stayed relatively the same, as shown in the graph below.



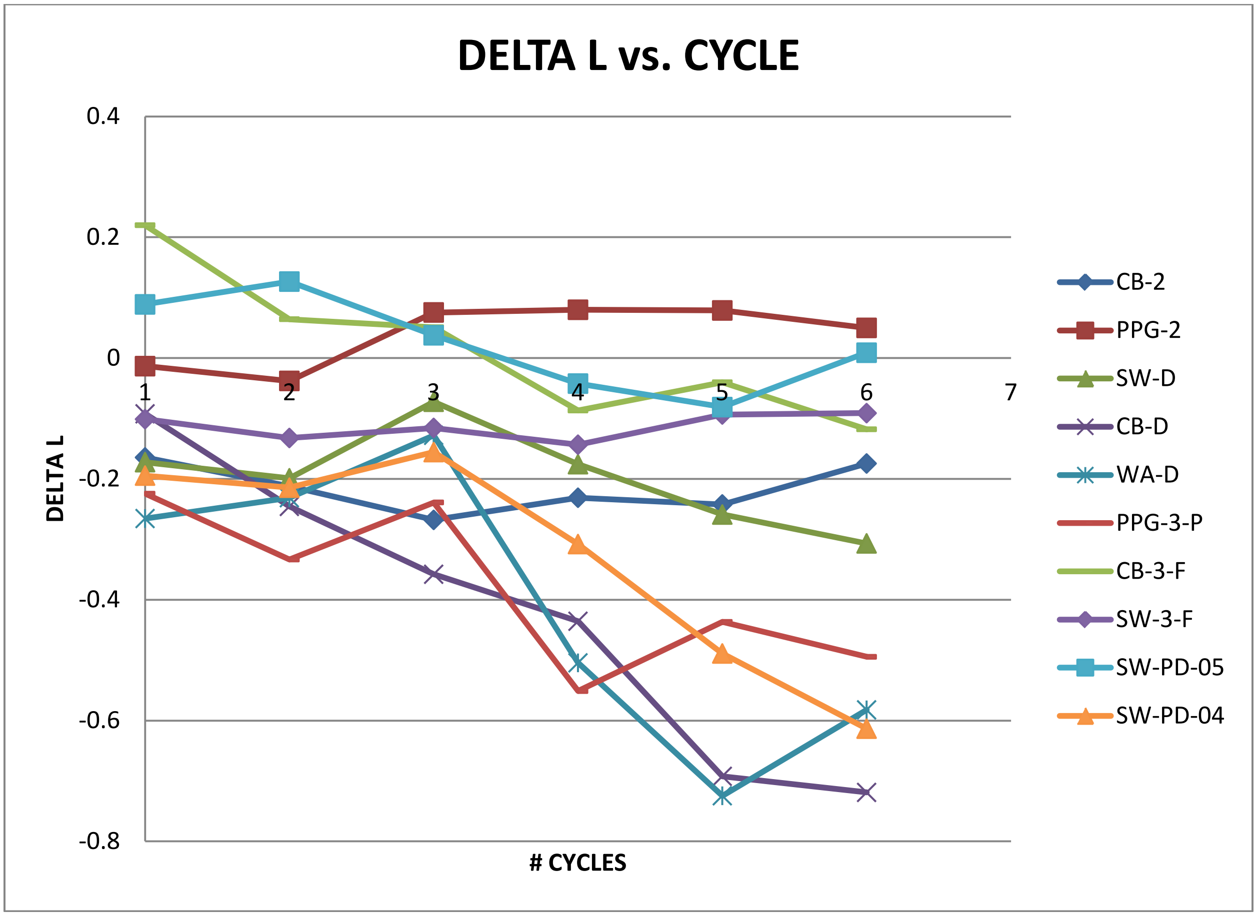
Graph #3: Percent Change in Gloss vs. Number of Cycles

II. Xenon Testing

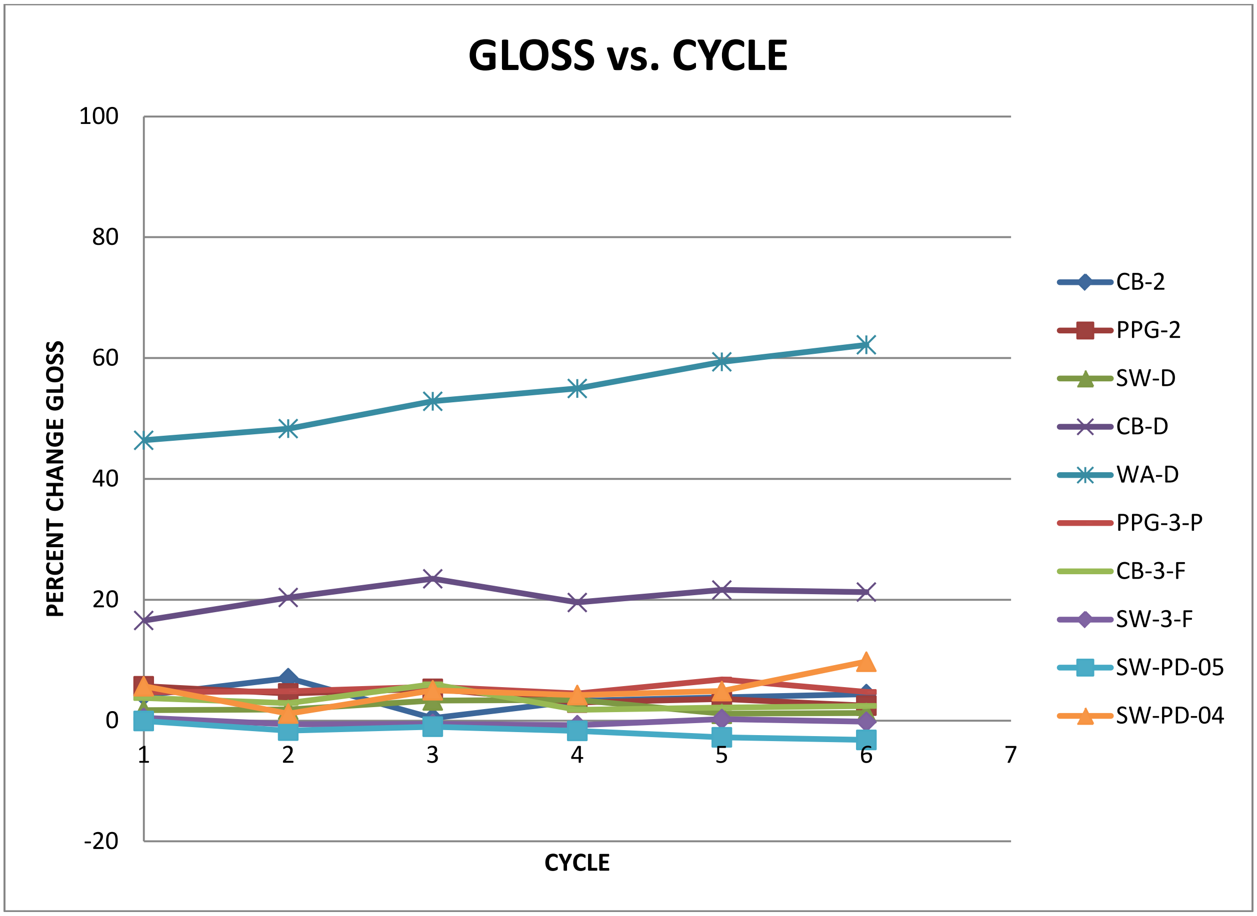
Six cycles have been completed for the Xenon Arc testing. Each cycle consists of one week under Xenon light. Graphs #4, 5, and 6 show ΔE, ΔL, and percent change in gloss versus the number of cycles respectively. The percent change in gloss for the Xenon testing has similar trends to the results of the Freeze/UV/Prohesion testing. Also, the fluoropolymer coatings are experiencing lower ΔE and ΔL values compared to the majority of the coatings. The two coat coatings are not showing higher ΔE and ΔL compared to the majority of the coating system, as was the case in the Freeze/UV/Prohesion testing.



Graph #4: ΔE vs. Number of Cycles



Graph #5: ΔL vs. Number of Cycles



Graph #6: Percent Change in Gloss vs. Number of Cycles